SOME PECULIAR PROPERTIES OF HIGH FREQUENCY CURRENTS

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To the average physician the term "high frequency currents" is anything but definite. The term has been so often misapplied that there is little wonder it is so generally misunderstood. In this paper it will be my aim to give an exact idea of what high frequency currents are and to illustrate experimentally some of their peculiar properties.

What is generally called the "alternating current" is a current of approximately sixty cycles per second, or, as it is sometimes called, 7200 alternations per minute. This means that in one second the current passes through 60 complete periods or cycles. Let us assume the current starts at zero value (see Fig. 1) and increases in a positive direction along the curve AB. When the current reaches B it has attained the maximum positive potential. It then decreases along the line B C until it again arrives at zero as shown at C. Continuing along the line C D E the current traces a path below the zero line of the same shape and size as that above, arriving finally at the point E on the zero line ready to commence another cycle. Along the line A B C is one alternation and along the line C D E is another. The complete curve A B C D E is a cycle. Hence there are two alternations, one positive and the other negative, to every cycle. Electricians always speak of so many "cycles per second" or "alternations per minute," and never reverse the terms. This is sometimes confusing to the non-technical mind as the manufacturer uses the more scientific term "cycles per second," while the local electrician usually refers to his current as so many "alternations per minute."

In commercial electric lighting and power work 25 cycles per second is called a low frequency current, while 133 cycles per second is considered a high frequency. To the physicist and manufacturer of therapeutic high frequency apparatus, however, 133 cycles per second is a low frequency. The latter consider a current one of high frequency only when it changes its direction thousands of times per second. These extremely rapid rates of vibration are not obtained by mechanical means, an electrical arrangement being far more satisfactory.

The questions have often arisen: What is a high frequency current? How are we to draw a line of demarcation between currents of low and high periodicity? I suggest the following definition of

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a high frequency current, considering these currents from the standpoint of the physician.

A high frequency current is one which is produced by the disruptive discharge of a condenser.

In suggesting the above definition I do so with the full understanding of the fact that under certain conditions the disruptive discharge of a condenser may be of comparatively low frequency, or may even not oscillate at all. These conditions, however, are rarely met with in practice and hence our definition is suitable for every case with which the physician will probably have to deal.

Assuming then that by the term high frequency currents we mean currents obtained by disruptively discharging a condenser, let us see how such currents are actually produced for therapeutic use.

There are three methods of generating therapeutic high frequency currents, the D'Arsonval, the Oudin and the Tesla method. The machine illustrated (Fig. 2) is so designed that any one of these methods may be used at will, that is, either D'Arsonval, Oudin or Tesla currents are produced. I shall try to show you wherein they differ.

In this paper I shall ask pardon for the frequent mention of my own machine. This frequent mention is necessary, furnishing, as it does, all the various currents necessary for the following experiments.

For an illustration let us entirely disconnect the Tesla coil regularly furnished with the apparatus, and lead the heavy oscillatory current, which ordinarily excites the primary of this coil, outside the cabinet. This result is accomplished by means of switches F and P in Fig. 2. Now connect this heavy oscillatory current to a coil, which is simply three turns of electric light wire wound into the form of a circle two and a half feet in diameter. By connecting metallic handles to the two extremities of the circle of wire and turning on the current, we obtain the high frequency current of D'Arsonval. This is nothing more nor less than the drop in potential across this crude coil caused by currents of extremely high frequency circulating through the coil. In practice the D'Arsonval current is obtained from binding posts D D in Fig. 2, and regulated with handle G. The frequency of the D'Arsonval current is high, but the voltage is necessarily comparatively low, being limited by the potential of the transformer charging the condenser, and governed by the length of the spark gap.

Oudin added what he called his "resonator" to the solenoid of D'Arsonval and thereby raised the potential of the currents produced. Since we cannot obtain something out of nothing, this rise in potential is at the expense of amperage. The Oudin current has a higher voltage than the D'Arsonval current, but correspondingly less amperage. A rough model of an Oudin resonator consists of a single layer of wire, the length of which, however, must be carefully

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proportioned to the wave length and frequency used. Let us see how we can increase the voltage by this simple device.

Place this Oudin resonator within the D'Arsonval coil and connect the lower end of the resonator to the coil itself. Turning on the current we notice the high potential discharge issuing from the top of the resonator. Bring a vacuum tube within the vicinity of the discharge and we notice it glows brightly. The high frequency currents have set up an intense electrostatic field in the neighborhood of the resonator and it is this rapidly varying electric stress which induces the currents within the tube and causes it to glow. Oudin currents are obtained from the machine by attaching the terminal Y to a special socket on the right hand side of the cabinet (not shown in Fig. 2). Oudin currents are then obtained from the other terminal Z.

It is but a short step from the arrangement of Oudin to that employed by Tesla. Simply disconnect the lower end of the resonator from the heavy wire coil and bring the plane of this coil so that it passes through the center of the solenoid of finer wire. We now have the bipolar coil of Tesla, the heavy coil being the primary winding and the finer wire the secondary. Although there is no visible connection between the primary and secondary windings, we see that powerful high frequency currents are induced from one coil to the other. Connect an X-ray tube to the secondary of this crude Tesla coil and we notice the characteristic green fluorescence of the Crookes' vacuum. It is rather strange, when you come to think of it, that these X-rays are being obtained from a simple coil of wire which is separated by fully one foot of space from the source of energy. When experimenting with high frequency phenomena, however, one becomes accustomed to remarkable effects and looks for them as a matter of course. Of course, in practice, this crude device is inefficient and inconvenient. Powerful Tesla currents are obtained for therapeutic and X-ray results from the terminals Y Z after detaching the special Oudin connection previously mentioned.

As to the relative merit of the D'Arsonval, Oudin and Tesla methods of current generation, I would say that it depends upon the use to which the current is to be put or the disease that is to be treated. When heavy amperage is essential the D'Arsonval method recommends itself, while for monopolar work requiring a higher potential the Oudin method proves more efficacious. As far as all around work is concerned, and for X-ray production, the Tesla method is by far the most appropriate. Each current has its use, however, and it is therefore better to have all at your disposal.

Now that I have shown the three methods by means of which high frequency currents may be generated, let us consider in detail one, and in my opinion the most important, of these methods. I shall now describe how a sixty cycle ordinary street lighting current of 100 volts may be transformed into a high frequency current of over a million volts and oscillating over a million times in a single

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second. I shall use the Tesla method for this illustration, since it is the one employed in the most modern highfrequency apparati of great power. This transformation is not the result of a single process, but consists of three separate and distinct transformations. We will now consider these in detail.

Referring to Fig. 3 we have here the wiring diagram of the Tesla circuit. It will be noticed I have marked the alternating current mains "low voltage, low frequency." This is the commercial alternating current which usually has a periodicity of 60 cycles, and a potential of approximately 100 volts. If the direct current only is obtainable a rotary converter is used to convert the direct current into the more desirable form of electricity.

The alternating current is now passed to the primary winding of a high potential transformer which changes the 100 volt current to one having a maximum potential of about 30,000 volts *but does not alter the frequency.* The current is still a 60 cycle current. This is the first step in the transformation of our low potential, low frequency current to one of high potential and high frequency. Notice the first step increases the voltage only, and leaves the frequency unaltered.

In the second step of the transformation the periodicity is increased, while the voltage is left unaltered. The high voltage, low frequency alternating current is led from the secondary of the transformer (Fig. 3) to a condenser of suitable capacity. In effect this condenser may be considered a large number of Leyden jars such as are employed with static machines. The purpose of this condenser is to store up electrical energy at a comparatively slow rate and liberate it rapidly, that is, as a disruptive discharge. Referring again to Fig. 1, say the condenser charges at an even rate along the line A B. The potential at the terminals of the condenser, and hence at the two terminals of the spark gap, rises until the insulating layer of air between the spark gap balls breaks down due to the intense electric stress. A discharge across the gap now takes place and the stored up energy of the condenser rushes across the gap.

To the unaided eye this discharge across the spark gap appears to be a single spark, but in reality it is composed of a large number of smaller sparks or discharges. In fact the discharge is oscillatory in character, surging backwards and forwards millions, and in some cases billions of times per second. These rapid discharges slowly die out, due to damping caused by heating and other losses. When the discharges have diminished in intensity, or entirely stopped, the spark gap assumes its original condition of high resistance. This allows the condenser to again become charged to a high potential and the above process is repeated.

An analogy to illustrate the charging of a condenser would be the case of a spring steel rod, one end of which is clamped in a vise and the other left free to vibrate. If this rod be drawn aside and suddenly released, it will oscillate to and fro until it finally comes to

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surface. Bjerknes demonstrated this experimentally with his famous resonator experiment. The human body, however, is not a good conductor of electricity as compared with a metallic wire and hence the action of high frequency currents with respect to a metallic conductor forms no criterion as to their behavior with respect to the human body which has a comparatively high ohmic resistance.

The skin effect in conductors decreases as the resistance of the conductor increases, and at the high resistance attained by the human body there is little doubt that the currents penetrate to the innermost portions of the conducting medium. How high frequency currents accomplish the results they are daily accomplishing, both in this country and abroad, with all sorts of apparatus, is a thing not explained by those who uphold the theory that these currents are superficial in their action.

I take this opportunity of introducing to the medical profession a new gap for high frequency apparatus. The construction of this device is so unique, and its operation so remarkable, that I think a description of it is not out of place in a paper of this character.

Most physicians have no doubt heard about the new mercury vapor lamp which was introduced a short time ago by Mr. Peter Cooper Hewitt. Some have possibly seen this new light, as it has been quite extensively adopted in photographic studios and to some extent used as an advertising medium. It is in the form of a tube about three feet long and one and one-half inches in diameter. The light emitted is rather disagreeable for some purposes, being practically monochromatic in character and almost entirely lacking in the longer wave lengths, such as red.

Some time ago my attention was attracted to this new device and it occurred to me to use it as a spark gap for high frequency apparatus. I later learned that such attempts had been made but for some reason or other the old form of spark gap was preferred. In the course of my experiments it became apparent why the new device had not been universally adopted. Under certain conditions its operation was ideal but unfortunately these conditions were not the conditions usually met in practice. To be more explicit the vapor gap worked well when a large amount of energy was used but was unsteady and erratic when currents such as ordinarily employed, were passed through it.

Now it so happens that the ordinary spark gap, composed of conducting electrodes separated by an intervening dielectric, operates very satisfactorily on light currents but fails completely when the current is increased beyond a certain well defined point. Fortunately what one gap lacks the other possesses and vice versa. It occurred to me to combine the two and thus get an ideal device. I did this and after considerable experimenting evolved the form I here describe. The gap is simply a glass bulb into which is sealed two platinum leading-in wires. A small pool of metallic mercury covers each of these wires. In operation the electric stress at the

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surface of the mercury increases until ionization takes place and a bridge of mercury vapor is formed. This mercury vapor forms a low resistance path for the oscillatory currents but immediately regains its initial high resistance upon the diminution of the electric stress at the surface of the electrodes. The gap is perfectly noiseless and operates with absolute steadiness.

There are a great many advantages of this new spark gap, or interrupter, over the old device. In the first place almost any amount of energy may be passed through it without ruining the oscillations. Those who have had to deal with high frequency apparatus, know that the spark gap has been the one part of the machine which was liable to cause trouble. If anything went wrong, this device was the first to receive attention. This new spark gap does away with all these difficulties. I do not hesitate to say that an apparatus equipped with this new gap could be started going and left operating for three months, day and night, and during all this time it would perform its function perfectly. This is a pretty strong statement but many experiments and observations demonstrate the truth of it.

The machine here illustrated is equipped with this new mercury vapor gap, a switch being provided by means of which the vapor device may be thrown out of use and the ordinary gap employed in its place. I shall now describe some experiments to illustrate the relative efficiency of the two spark gaps.

Turning the Frequency Changing Switch (F in Fig. 3) on the machine to HIGH let us turn on the current. As long as the energy passing through the gap is small the ordinary device works very well but it fails almost completely when we turn the Extra Power Switch which greatly increases the current flowing through the machine. Now the way manufacturers and designers surmounted this difficulty was to greatly increase the size of their condenser. In this machine this is accomplished by turning the Frequency Changing Switch to LOW, and a great increase in power is obtained. With a small condenser working on a high frequency and heavy power, the ordinary spark gap is practically worthless. If the condenser capacity be increased the power of the apparatus is increased, but unfortunately an increase in the capacity of the condenser means a decrease in the frequency of the oscillatory currents produced. The problem for the designer was to obtain the necessary power and still keep the frequency high.

At this point the mercury vapor gap comes to our rescue. Thus we turn this switch and thereby put the vapor gap in circuit. Proceeding exactly as we did before, the oscillations are not destroyed as was the case when the ordinary gap was employed. Furthermore I wish to call attention to the fact that even on the low frequency the energy of the machine has been greatly increased by the introduction of this new gap. Turn the Frequency Changing Switch to LOW and we get a greatly increased power of the discharge.

With the ordinary gap the condenser is charged from one to

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four or five times on each alternation or half cycle of the current wave, depending on the amount of energy used to charge the condenser. If more energy is applied with the idea of charging the condenser more rapidly, or if the condenser capacity is decreased in order to raise the frequency, the oscillations are almost entirely destroyed and the output of the machine greatly reduced.

With the mercury vapor gap these defects are not present. A small condenser capacity may be used and a powerful current without destroying the oscillations. The result is a high frequency current of enormous periodicity and large output. I have succeeded in charging a condenser as many as one hundred times on a single alternation or half cycle of the current wave. This is no less than 12,000 times per second! Each one of these 12,000 condenser discharges oscillated at the rate of over a million times per second! This certainly is high frequency.

Let us consider an experiment which will show in a beautiful manner the rate at which the condenser is being charged and discharged. Let us take a thin vacuum tube which is so arranged that we can whirl it in a circle while it is being illuminated by the high frequency current. If we hold this tube in the vicinity of one terminal of the apparatus, it glows with what appears to be a steady light; of course this light is not steady, as it is produced by a vibratory current. If we now whirl the tube in a circle and separate the images which follow each other with great rapidity, the number of groups of images will equal the number of alternations of the current per second, that is, twice the number of cycles. The number of images per group will show how many times the condenser charges and discharges on each half cycle. Of course each one of the separate images might be further decomposed and shown to be a collection of a number of weaker images corresponding to the actual oscillations of the current. We would have to employ a different means than here used to make this last separation, however, as the current oscillates at such an enormous frequency.

Using a large condenser capacity and low frequency with a small amount of charging energy, we notice that the condenser charges and discharges only once on each alternation or half cycle of the current wave. As we increase the charging energy we see two images to each group, which indicates the condenser is charged and discharged twice on each alternation. Keeping the charging potential constant and slowly increasing the energy passing through the transformer, we notice we can charge the condenser any number of times at will. As the energy is still further increased the images become irregular. This is the point where the ordinary spark gap begins to fail to perform its function of causing the current to oscillate regularly. We have now arrived at a point when the charging energy is too great in proportion to the other constants in the circuit and poor oscillations result. This is where the mercury vapor comes in. Put this new gap in circuit and we see that the images are again perfectly regular. Increasing the charging energy only

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increases the number of images and in no way makes them irregular. A further increase of energy makes it impossible to count the images with the crude method we are using. If we could count them, and they are easily counted with a more refined method of observation—we should see they were perfectly uniform and regular. I think this demonstrates the advantages of the mercury gap over all other forms of current interrupters for high frequency apparatus.

In the foregoing description I have endeavored to give a description of what I consider the best method of generating currents of high frequency and potential. I have started with a current having a potential of only 100 volts and a periodicity of 60 cycles and gone through the processes by which this current is transformed to one having an extremely high potential and enormous frequency. Of course, I have only considered a simple case but the principle is the same, however complicated the modification of the apparatus.

Over ten years ago Nikola Tesla astonished the world with his wonderful experiments employing currents of high frequency and potential. He passed large quantities of energy through his body with only slight sensory effects, and performed other startling experiments which clearly demonstrated that electricity of this nature did not behave as did ordinary currents. Since Tesla's early demonstration, we have learned much regarding the peculiar properties of what he termed "alternate currents of high voltage and great frequency." Let us now consider some of these peculiar properties. considering as a source of energy the machine here illustrated. which is known as the Ovington Electro-Therapeutic and High Frequency Apparatus.

Perhaps the most noticeable peculiarity of high frequency currents is that they flow to an insulated conductor; that is, a complete circuit is not required as in ordinary cases. Thus, we start the machine in operation and hold near one terminal a piece of sheet metal suspended by a silk cord. The discharge passes to the metal plate although it is well insulated. In the same way if we connect the body with one terminal, the electricity is flowing through the connecting wire just as truly as though it were connected with the opposite side of the machine. and a complete metallic circuit were formed. Let us see if we can find a reason for this.

If we place a person upon an insulated platform and connect him with one terminal of a static machine, or other source of direct current electricity, there is a momentary rush of current through the connecting wire to the body of the person under treatment. If the effects of leakage be neglected, this rush of current is only of very short duration and persists until the body of the person connected with the machine is charged to the same potential as the machine itself. If a continuous flow of current is desired more than one connecting wire must be used.

In the above mentioned case we assume a direct current was used. Let us see what takes place if a current of high frequency be

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substituted, that is, connect the person under treatment with a high frequency apparatus exactly as was done in the case of the static machine. To make the two cases alike the insulated platform may be employed, although with high frequency currents this cumbersome device is entirely unnecessary.

With high frequency currents the result of our experiment is entirely different from the previous case. We have a condenser or capacity effect now which is the most important thing to be considered. The person corresponds to one coating of a Leyden jar, the space surrounding him is equivalent to the glass separating the coatings, and the walls of the room, or other surrounding objects, may be considered as the other coating. We have in effect, therefore, a condenser connected to one side of our high frequency apparatus. Now it is a fact that condensers allow high frequency currents to pass through them and the crude condenser formed as above described is no exception to the rule. Currents come from the machine along the connecting wire as conduction currents, and pass from the body of the person under treatment, into the surrounding space as the displacement currents of Maxwell. The currents flow through the body of the patient, therefore, although only one terminal of the machine is used.

By connecting a person with one terminal of the machine an electrostatic bath may be administered. Although he is being charged and discharged at an enormous rate, no sensory effect is produced. He does not know whether the current is on or off. An effective way to demonstrate the presence of the current in his body is to hold a vacuum tube near him while the current is on. The tube will glow brightly although a considerable space separates it from his charged body. Notice also that the tube glows with undiminished brightness whether it is held near his head or feet. Every part of his body is surrounded with an intense electrostatic field. This is one method of therapeutic treatment, special vacuum electrodes being used for the various cavities of the body.

If we take six ordinary sixteen candle power incandescent lamps connected to one terminal of the apparatus and to a metal electrode, to be held in the hand, we can pass enough current through a person to light all six of these lamps. The lamps burn brightly and yet no sensory effect is produced. This is a most valuable and peculiar property of high frequency currents, since a large quantity of energy may be used therapeutically with little or no inconvenience to the patient.

A rather striking experiment is the deflagration of metals by high frequency currents passing through the body of the experimenter.

Take a short piece of iron wire and hold it securely with pliers. Allow the high frequency discharge to pass to the wire and let us see the result. The large amount of energy passing is sufficient to melt the metal, the characteristic scintillations being visible as the molten globules drop upon the floor.

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Another peculiar property of high frequency currents is their apparent dislike for a turn in their conductor. They do not object very seriously to flowing along approximately straight conductors, but great difficulty is apparent when they are forced to travel through looped conductors or through a coil of wire. This is due to the fact that the frequency is high and currents of high frequency find difficulty in flowing in paths of considerable inductance. Let us illustrate this point with an experiment.

Let us take a piece of common electric light wire coiled so as to form three loops or circles of wire. Connect with the two ends of this coil an incandescent lamp. On the ordinary street circuit this heavy copper wire would melt before enough current would flow through the lamp to light it. The path of least resistance is through the heavy copper wire and hence the current flows through it in preference to the path through the lamp, which is a path of comparatively high resistance. But in the case of high frequencies we have other factors than the relative resistance of the circuits to consider. Inductance, as well as resistance, must be taken into account when currents of high periodicity are employed. When the rate of vibration is as high as we are considering in these experiments inductance is by far the more important factor. Resistance is of little consequence. The combined effect of resistance and inductance is called impedance, and for this reason these experiments are illustrations of impedance phenomena.

Let us apply a powerful oscillatory current to the lamp and coil of wire previously mentioned and the lamp will burn despite the fact that it is practically short circuited by a heavy copper wire of low resistance. Part of the current prefers the path of high resistance through the lamp rather than the path of low resistance through the heavy copper wire.

A peculiarity of high frequency currents worthy of our attention is that they pass readily through what we call insulators. For instance, a plate of glass about ¼ inch thick, which would serve as an efficient insulator for currents of ordinary potentials and frequencies, when used with high frequency currents, might as well be of copper as far as its restraining action on the currents is concerned. Place it between the terminals of the machine and the discharge passes through it with little effort. Furthermore there is but slight tendency for the current to jump around the glass, even when the terminals are brought near the edge of the plate. They actually seem to prefer to go through the glass rather than around it.

To prove this effect is caused by the high frequency character of the current we can lower the periodicity by throwing the Frequency Changing Switch on the machine (F Fig. 2). At this lower frequency the current still passes through the glass to a certain extent but it has more of a tendency to jump around the glass than it did at the higher frequency. Where the current is a direct one, as in the static machine, it would jump around the glass in every case

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before it would go through it, unless it was powerful enough to actually puncture the glass.

A vacuum electrode is simply a piece of glass tube sealed up at each end and exhausted to a white vacuum. The current jumps to it as if it were metal. The high frequency currents find little difficulty in passing through the wall of the tube to the conducting vacuum within.

It is this ability of high frequency currents to go through glass which makes a high frequency apparatus, producing a really high frequency current, very economical in the use of X-ray tubes. The current passes harmlessly through the walls of a tube instead of passing through it disruptively and puncturing it. This is true, however, only of coils generating very high frequency currents. Many high frequency coils which generate currents of comparatively low frequency, are destructive of tubes.

To illustrate the great power of this apparatus we can allow the discharge to actually melt its way through a solid glass plate. To do this it is only necessary to concentrate the current at one point. Place the glass plate between the main terminals of the machine and turn on the current. At first the discharge passes as before harmlessly through the insulation. It flows through as a displacement current of Maxwell, however, and not as an ordinary conduction current. These displacement currents, nevertheless, heat the material through which they pass just as conduction currents do, and this is what happens in the glass. It becomes rapidly heated, due to the immense amount of energy passing through such a small area. Now, when glass is heated its insulating qualities are impaired, that is, it becomes more or less of a conductor. When this takes place, the current finds it easier to pass through the glass plate as an ordinary conduction current, rather than as a displacement current. It passes disruptively instead of harmlessly through the glass, and in doing so punctures the glass. By slowly moving the plate when it is between the terminals we can cause the discharge to melt a path for itself, and in this manner melt any given design into the glass. By tapping the glass lightly or spilling a small quantity of water upon it during this operation, the glass breaks along the line the discharge passes. This is a rather novel way of cutting glass.

The property of currents of high frequency and potential to pass through insulators is utilized in a novel and very useful method of treatment. I refer to what is called the plate glass treatment.

In cases of indigestion and constipation the plate glass treatment is particularly efficacious. In administering this treatment the patient holds a piece of plate glass over the abdomen or other portion of the body to be treated, and the point electrode is then held a short distance from the surface of the glass. The discharge passes from the point to the glass and spreads out in purple streamers over a considerable area. The patient experiences practically no sensory effects during this treatment other than a slight warmth over the treated area.

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With the extremely high frequencies we are considering the effects of electrostatic induction are marked. D'Arsonval utilized this fact by surrounding his patients with a solenoid of wire through which he passed currents of high periodicity. This procedure bathed the patient in a rapidly fluctuating electrostatic field which gave rise to powerful induced currents within the body of the person under treatment.

With the apparatus here illustrated it is not necessary to use the cumbersome solenoid of D'Arsonval. In its place may be used what I have termed an Electrostatic Ring. This is simply a few turns of heavily insulated copper wire wound into the form of a ring. To those who have used the bulky solenoid of D'Arsonval it is unnecessary to emphasize the advantages of this more compact form of coil.

At first thought it might be said that an inducing conductor of this form would only induce currents in the patient's body in the vicinity of the plane of the coil, but such is not the case. I have made experiments which would go to prove that by surrounding a patient with an inductor of the above description, powerful induced currents may be set up throughout the entire length of the body. We can demonstrate experimentally the intensity of the electrostatic field produced by this appliance.

Connect the Electrostatic Ring with a current on the machine called Heavy Current Oscillatory. This oscillatory current is of enormous amperage and when circulated in a coil of wire produces very powerful electrostatic effects.

Take another coil of wire similar to the coil connected to the machine, except that it has more turns of wire in its construction—in these experiments the coil connected with the machine is the primary winding and the other coil the secondary winding of a crude Tesla transformer, and connect an ordinary incandescent lamp with the secondary coil of this high frequency transformer and bring the coils into the electrostatic field produced by the primary ring. The lamp lights brightly although over a foot of space separates the two coils. The energy passes from the primary ring to the secondary as a rapidly varying electrostatic stress in the ether. We have, on a small scale, the transmission of power without wires.

In place of the lamp in the foregoing experiment let us use a small piece of iron wire, and the current heats the wire when the secondary ring is brought near the primary. When we place the secondary directly upon the primary the iron wire is melted.

In a previous experiment I referred to a rough model of an Oudin resonator. In this experiment the secondary coil or resonator part was connected at its lower end with the primary. Let us repeat this experiment but not connect the two coils together. Place a coil of fine wire on a piece of plate glass and attach the lower end of the wire to a metal handle held in the hand. As this wire coil is brought into the electrostatic field the discharge streams from the uppermost turns, although over a foot of space separates the coil of wire from the inducing ring. As we raise this portable secondary

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out of the field of force the energy decreases, although the discharge is still perceptible when over three feet of space separates the two coils.

It has often been stated that high frequency currents were all well enough for therapeutic application but were not adapted as a generator of the X-ray. This opinion is generally held and is probably due to the fact that high frequency apparatus employing other than the Tesla principle is not suited to X-ray generation. The new type of Tesla apparatus, however, which has recently attained a high state of perfection and is distinctly an American production is a powerful producer of the Roentgen radiations, in fact is often to be desired over the induction coil and static machine. By employing a suitable form of tube X-rays may be obtained, using high frequency apparatus, which equal in definition those produced by a tube excited from either a coil or static machine. The rays generated are far more powerful than those which can be obtained with the ordinary static machine and compare favorably with those generated by an induction coil.

The mechanical simplicity of construction and operation of the high frequency apparatus should appeal to the medical profession, where, more than in any other profession, powerful and exact results are desired. In high frequency apparatus for the alternating current there is no revolving or movable part whatever. The current is taken directly from lighting mains and by a series of purely electrical transformations is raised to an enormous potential and periodicity. In this process no mechanical device, with its liability to get out of order, is employed. The great advantage of this is evident.

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Wireless telegraphy depends for its success upon the propagation of Hertzian waves in the ether and Hertzian waves are in turn dependent upon high frequency currents for their production. Some time ago it occurred to me to use my apparatus as a transmitter in wireless telegraphy and the results were so satisfactory that we now issue instructions for repeating these experiments, as well as supplying the necessary accessories to those who do not care to construct them for themselves. To give an idea of the simplicity of the apparatus employed to demonstrate wireless telegraphy is the purpose of the following experiment. Fig. 4 is a diagrammatic view of the receiver. As will be seen it is of such a construction that anyone can make it at a slight expense. The simplicity of construction, however, is no criterion of efficiency of the device, as this receiver as shown is very sensitive and may be employed over considerable distance.

The apparatus shown in Fig. 2 is a transmitter par excellence, but we must construct a receiver to detect the electrical waves. A receiver may be constructed if the following articles are obtained: A common sewing needle, two pieces of carbon such as used in batteries or to replenish street lighting arc lamps, one dry battery and

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an ordinary telephone receiver. Remarkable as it may seem, a very sensitive wireless telegraph receiver may be constructed from these simple materials.

File the two pieces of carbon so that each will possess a smooth, sharp edge at least an inch long. Get the edge as sharp as possible. Support these prepared carbons about an inch apart in such a manner that they are insulated from each other and have their sharp edges parallel and uppermost. Connect up the apparatus as shown in the cut.

Connect one of the main terminals of the high frequency apparatus we are to use as transmitter to the ground and the other to a vertical wire or antenna. The length of this wire will vary with the distance signals are to be transmitted. For a short distance a wire ten feet in height will be sufficient.

Provide a similar ground connection and aerial conductor for the receiving station as shown in the cut.

If it is only desired to transmit signals across one or two rooms, or from one part of the house to another, it is often not necessary to use the ground connection. In its place may be used a sheet of tin foil, a tin wash basin, or any other large metal object to serve as capacity.

To receive signals place the sewing needle across the two carbon knife edges and the receiver is ready. Turn the current on and off at the machine by means of the Auxiliary Control Switch. Every time the current is turned on at the transmitter a singing noise should be heard in the receiver and this noise should persist as long as the current is on.

Often when the receiver does not respond evenly its operation may be improved by shifting the position of the needle on the carbon knife edges. As mentioned before these edges should be as sharp as possible.

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In this paper I have selected only a few of the very many wonderful and intensely interesting experiments which may be performed with currents of high potential and great frequency. The field is so broad and the work so instructive and interesting, that one cannot start experimenting even in a small way, without discovering many new and peculiar properties of these currents. When we look back upon the past and consider the great strides which have been made and the therapeutic results accomplished with high frequency currents, who shall draw the boundary line for the expansion of the future?

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